VMAD SG2 on Virtual/Simulation testing

3rd Meeting

4 November 2020

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Agenda

- Actions from the last meeting
- Review of Master Document
- Answers on Sim SG strategy
- Output for VMAD 14 (WebEx) 5-6 November 2020
- Next Steps

ACTIONS FROM THE LAST MEETING

- (All) To provide feedback on common definitions - complete
- (Lili/Audi) Provide a summary on Static Analysis in Functional Safety (ISO 26262) – complete
- (Claus/Germany) Provide a summary of SetLevel4to5
- (Kodaka-san/JAMA) Provide a summary of ISO 34502 – complete
- (Japan) Provide a summary of DIVP - Complete
- (Siddartha/UK) Provide a summary of the other activities under ISO 3450X – complete
- (Gil/SAFE) Provide a summary of ASAM OpenX activities – complete
- (Barnaby/CLEPA) add references to the definitions used – complete
- (Biagio/EC and Barnaby/CLEPA) Further elaborate on the scope of the SG – complete
- (Biagio/EC and Barnaby/CLEPA) Draft SG presentation for VMAD 14 (the scope of the SG and linking the literature review to each scope item) – complete

Review of the NATM Master Document Chapter 6 on simulation/virtual testing

- Comments to Chapter 6 were provided by Germany, Japan, UK, NL
- After bilateral discussions with the relevant parties and internal reflection the following main changes have been applied to the document and submitted for consideration to the VMAD co-chairs:
  - Par 6.3. The sentence «Through this approach, ***an assessor can generate knowledge for validating an ADS*** in an agile, controllable, predictable, repeatable and efficient manner » is changed into the following: «Through this approach, ***an assessor can get confidence about the ADS based on the simulation and validation that was performed by the developer*** in an agile, controllable, predictable, repeatable and efficient manner »
  - Par 6.4 has been deleted as it was already included in Par 6.1

Review of the NATM Master Document Chapter 6 on simulation/virtual testing

- Firts bullet point of par 6.5 (now 6.4) has been amended with an example. In particular the text has changed into «entirely inside a computer (referred to as Model or Software in the Loop testing, MIL/SIL), with a simulation model of the elements involved (***e.g. a simple representation of the control logic of an ADS***) interacting in a simulated environment; and/or»

- Open-loop simulation. Although possible, open-loop simulation has been considered less suitable than closed-loop simulation for ADS validation. Therefore the following two sentences have been added respectively to 6.6 and 6.7 (now 6.5 and 6.6)

  - ***[…] the applicability of open-loop simulation in the ADS validation may be limited.***

  - **For ADS validation it is expected that mainly closed-loops simulations and virtual testing will be considered.**

Review of the NATM Master Document Chapter 6 on simulation/virtual testing

- Two weaknesses have been added to the Table of par. 6.11 (now 6.10)
  - ***Risk of over-reliance. Without proper consideration of simulation models' intrinsic limitations, a risk exists to put too much emphasis on simulation results without sufficient proof of their validity by physical testing***
  - ***Credibility. ADS validated on the basis of simulation results may suffer low credibility in the public opinion.***
- The followig sentence has been added to to par 6.11 (about the maturity of the pillar): «***Topics to be addressed are for instance the validation requirements (when is a model valid for what purpose).***»

Review of the NATM Oustanding issues Section simulation/virtual testing

- The table was empty and the document received only 1 comment (from Japan). Mirroring what was included for test-track and real-world testing, the following outstaning issues have been added (which also reflect the initial discussions in the group):

1. Identify best practices/procedures that currently exist regarding simulation and virtual testing. Identify technical resources/tools that still need to be developed (or what externally developed resources should be referenced in the NATM). What are supporting components of the methodology (e.g., dictionary of terms, scenarios from SG1a)?

2. In consultation with SG1a, identify the scenario elements of an ODD that can be reliably reproduced in a simulation/virtual test (e.g., ADS and/or component operations; different roadway layouts; interactions with a variety of different types of road users and objects exhibiting static or dynamic behaviours; and, environmental conditions, among many others factors), including how they are measured.

Review of the NATM Oustanding issues Section simulation/virtual testing

3. Determine the various levels of abstraction of scenarios required for simulation/virtual test scenarios.

4. Outline/describe the various methods/procedures for virtual testing that could be used to assess an ADS' safety requirements.

5. Identify the information/data produced using simulation/virtual testing that can provide a clear, objective assessment of the ADS performance

6. Identify how simulation/virtual testing could be used to validate specific functional safety requirements established by FRAV. Which functional requirements can be partially assessed by simulation/virtual testing (e.g., system safety, operational design domain, object and event detection and response (OEDR), human factors)?

7. Define a robust as well as flexible methodology for the simulation tool-chain validation with the support of data collected during track and real-world testing

Review of the NATM Oustanding issues Section simulation/virtual testing

- The list has submitted to the VMAD co-chairs with the suggestion to include in one of the items the comment received that «***test method should not be related to specific software.***»

SIM SG STRATEGY

Considering the current NATM structure, how simulation/virtual testing will be used, in practical terms, in the ADSs safety validation?

Which is the most important and urgent task for this sub-group?

Do you see simulation/virtual testing used by third parties and certification bodies in the future AV certification process? If yes, how far in time do you see this possibility?

Still open for feedback until next SG meeting 11th November 2020.

PROPOSED SCOPE

- Define common definitions
- Literature review
- Provide description of different virtual testing methods and how they can be used together to support effective ADS validation (Sim type vs functional req vs number scenarios). Define the documentation requirements for OEMs – to be reviewed at Audit.
- Describe how simulation can be used to support other test methods e.g. track tests, real world tests.
- Describe methods for validating virtual testing toolchains.
- The future of simulation – tools held by 3rd parties.
- Review if methods can be agnostic to system type (ADAS / ADS)?
- Review existing text in Master Document e.g. Pros and Cons of Simulation
- Track FAQs

PROPOSED STRUCTURE

Content		References			
Main Body	Common definitions	Academic papers			
	Describe general ADS and simulation validation processes	UNECE R140	(EC) 2018/858	NASA-STD-7009A	
	Description of different virtual testing methods and how they can be used together to support effective ADS validation	ISO TR 4804	Industry safety reports e.g. Waymo, Zoox etc		
	Describe how simulation can be used to support other test methods e.g. track tests, real world tests.				
Annex	Define the documentation requirements for OEMs	NASA-STD-7009A			
	Describe methods for validating virtual testing toolchains.	IAMTS WG3	AEBS 12-07	NASA-STD-7009A	DIVP Japan
	The future of simulation – tools held by 3rd parties	ASAM OSI			

The groups attention should focus on:
- How simulation can support other test methods
- Validation of the toolchain + KPIs for simulation accuracy

VMAD Sim SG will provide a working draft at the next VMAD meeting.

ANNEX

COMMON DEFINTIONS

- *‘Model-In-the-Loop’* (MIL) is an approach which allows quick algorithmic development without involving dedicated hardware. Usually, this level of development involves high-level abstraction software frameworks running on general-purpose computers.

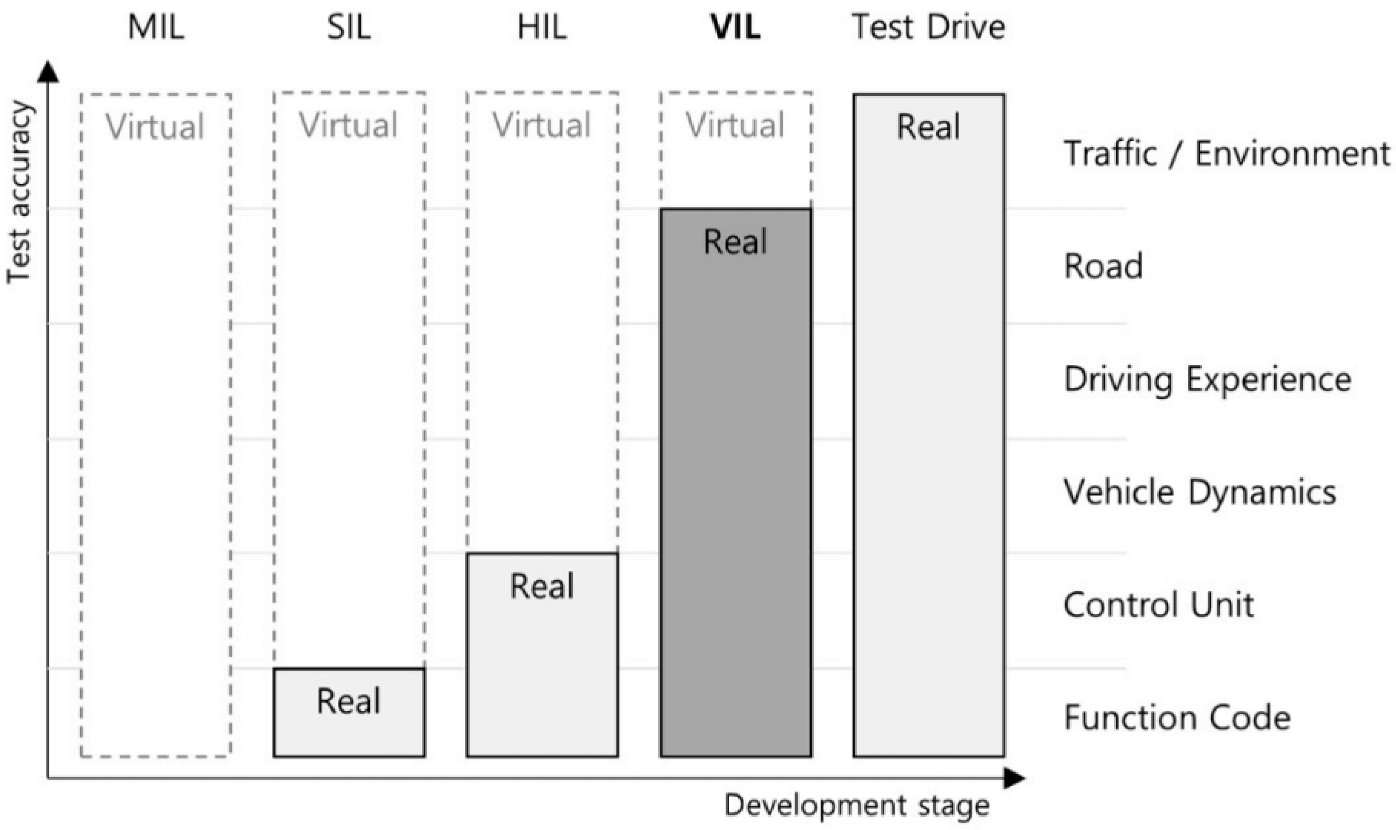
- *‘Software-In-the-Loop’* (SIL) is where the actual implementation of the developed model will be evaluated on general-purpose hardware. This step requires a complete software implementation very close to the final one. SIL testing is used to describe a test methodology, where executable code such as algorithms (or even an entire controller strategy), is tested within a modelling environment that can help prove or test the software

- *‘Hardware-In-the-Loop’* (HIL) involves the final hardware running the final software with input and output connected to a simulator. HIL testing provides a way of simulating sensors, actuators and mechanical components in a way that connects all the I/O of the Electronic Control Units (ECU) being tested, long before the final system is integrated.

- *‘Vehicle-Hardware-In-the-Loop’* (VeHIL) is a fusion environment of a real testing vehicle in the real-world and a virtual environment. It can reflect vehicle dynamics at the same level as the real-world and save the cost of constructing an external environment for testing. It can be operated on a chassis dynamometer or on a test track.

COMMON DEFINTIONS

- *‘Driver-the-Loop*’ (DIL) is typically conducted in a fixed-base driving simulator used for testing the human–automation interaction design. DIL has components for the driver to operate and communicate with the virtual environment.



COMMON DEFINTIONS

- *'Closed Loop Testing'* means a simulation environment does take the actions of the system-in-the loop into account. Simulated objects respond to the actions of the system (e.g. system interacting with a traffic simulatin model)

- *'Open Loop Testing'* means a simulation environment that does not take the actions of the system-in-the loop into account (e.g. system interacting with a recorded traffic situation)

- *'Validation of Simulation'* is the process of determining the degree to which a model or a simulation is an accurate representation of the real world from the perspective of the intended uses of the simulation.

- *'Verification of Simulation'* is the process of determining the extent to which an simulation is compliant with its requirements and specifications as detailed in its conceptual models, mathematical models, or other constructs.

- *'Model'* is a description or representation of a system, entity, phenomenon, or process

- *'Simulation*' is an imitation of the behavioral characteristics of a system, entity, phenomenon, or process.

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COMMON DEFINTIONS

- *Stimulation'* is a type of simulation whereby artificially generated signals are provided to real equipment in order to trigger it to produce the result required for verification of the real world, training, maintenance, or for research and development.
- *'Deterministic'* is a term describing a system whose time evolution can be predicted exactly
- *'Probabilistic'* is a term pertaining to non-deterministic events, the outcomes of which are described by a measure of likelihood
- *'Stochastic'* means a processes involving or containing a random variable or variables. Pertaining to chance or probability.
- *'Calibration'* is the process of adjusting numerical or modeling parameters in the model to improve agreement with a referent.
- *'Abstraction'* is the process of selecting the essential aspects of a source system or referent system to be represented in a model or simulation, while ignoring those aspects not relevant to the purpose of the model or simulation. Any modeling abstraction carries with it the assumption that it does not significantly affect the intended uses of the simulation

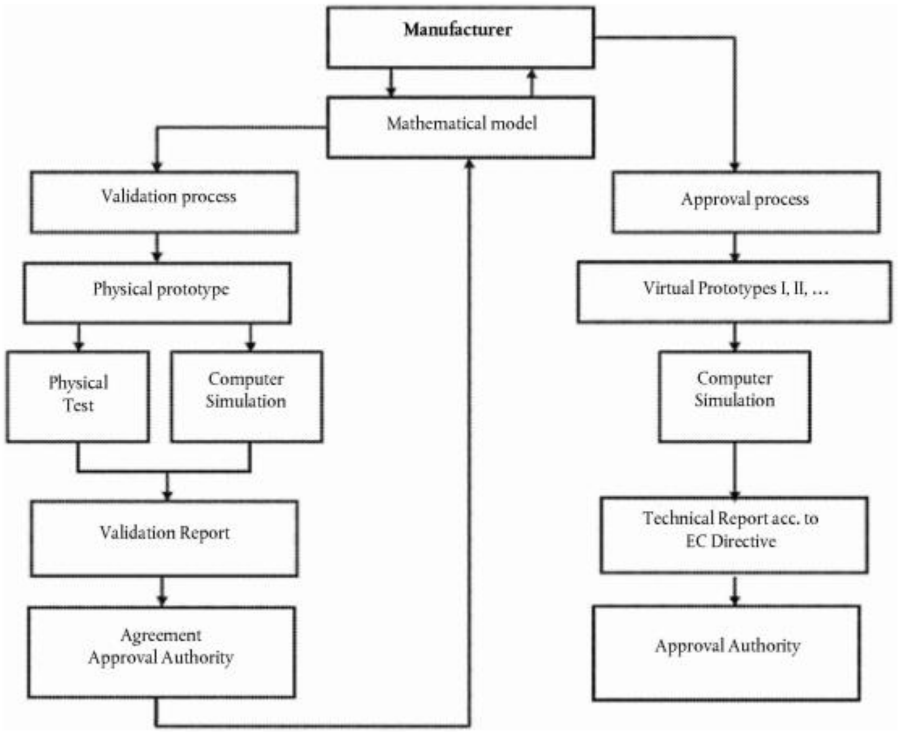
LITERATURE REVIEW

UNECE R140 & (EC) 2018/858

Describes the validation process for a simulation (mathematical model) used in the type approval process.
Applicable to a specific set of regulatory acts.

Appendix 3

Validation process



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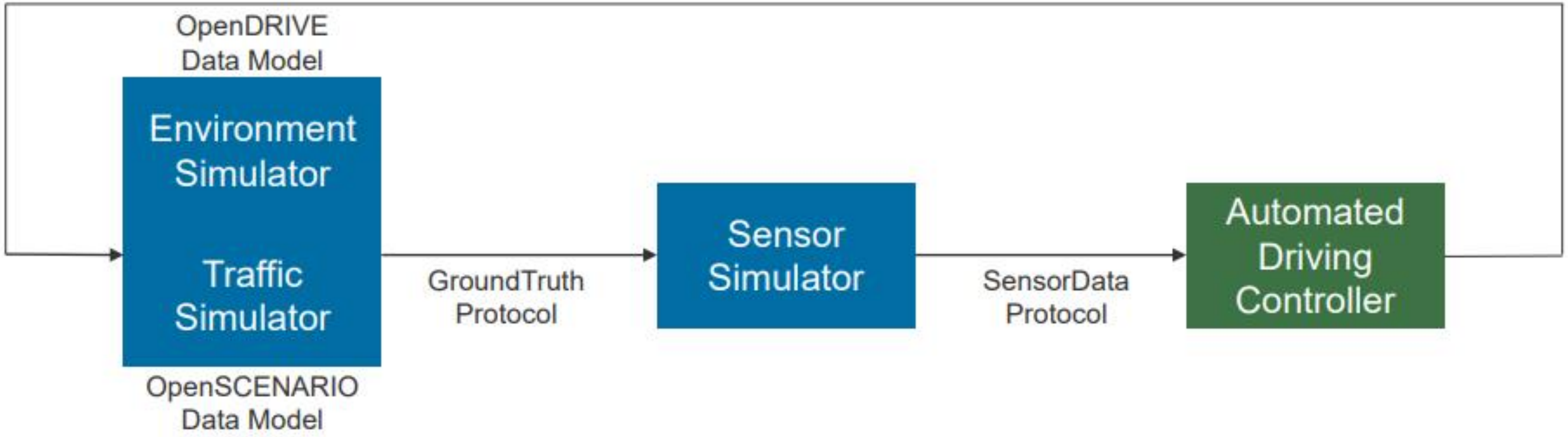
LITERATURE REVIEW

ASAM OSI

- OSI: Open Simulation Interface
- A generic interface for the **environment perception of automated driving functions in virtual scenarios**.
- Contains an object-based environment description using message formats for two types of data:
  - GroundTruth: gives an exact view on the simulated objects in a global coordinate system.
  - SensorData: describes the objects in the reference frame of a sensor for environmental perception.

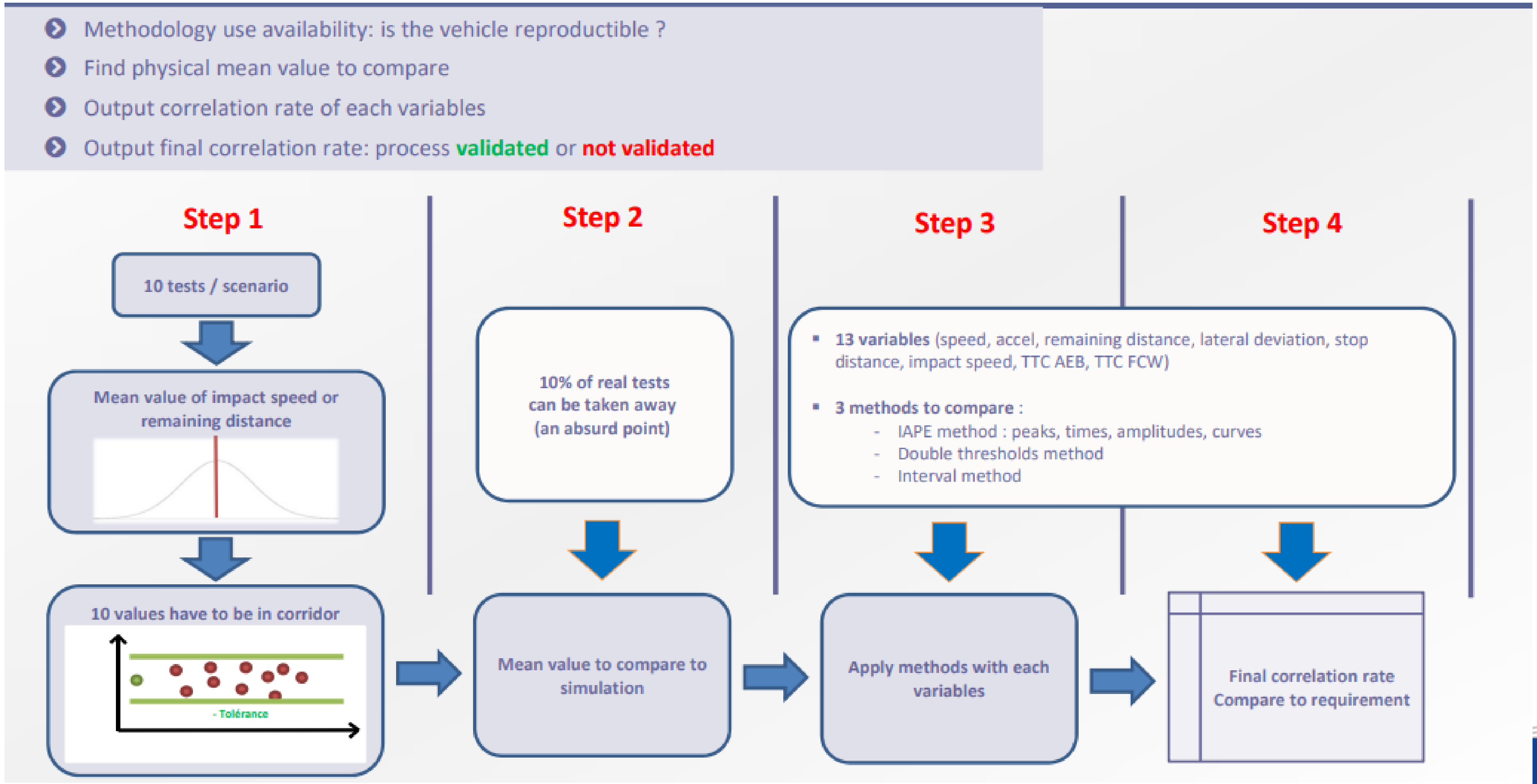


LITERATURE REVIEW

AEBS 12-07 (UTAC) Validation method: Virtual testing

- Describes how different Simulation tools may be used during V&V. e.g. MIL, SIL during verification and HIL, VIL used in validation.
- Proposes a 4 step strategy for validating simulation results + KPIs (IAPE method to quantify correlation rate)

AEBS-12-07

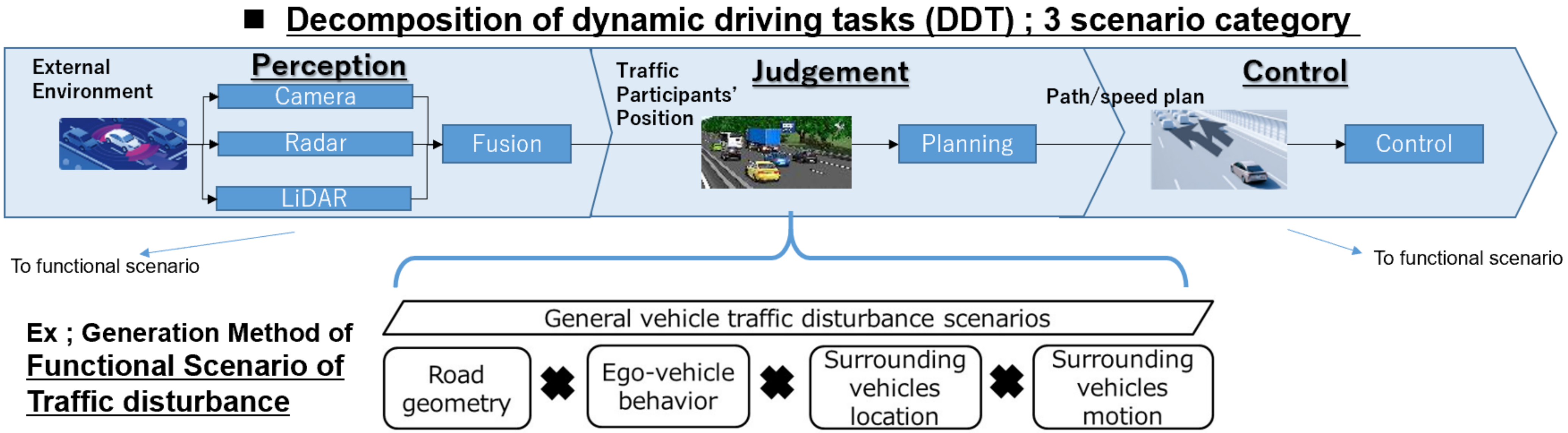


LITERATURE REVIEW

ISO 34502

- Describes methods for scenarios to be structured in a way that takes into account the necessary elements for an ADS to perform the DDT.

ISO 34502 summary

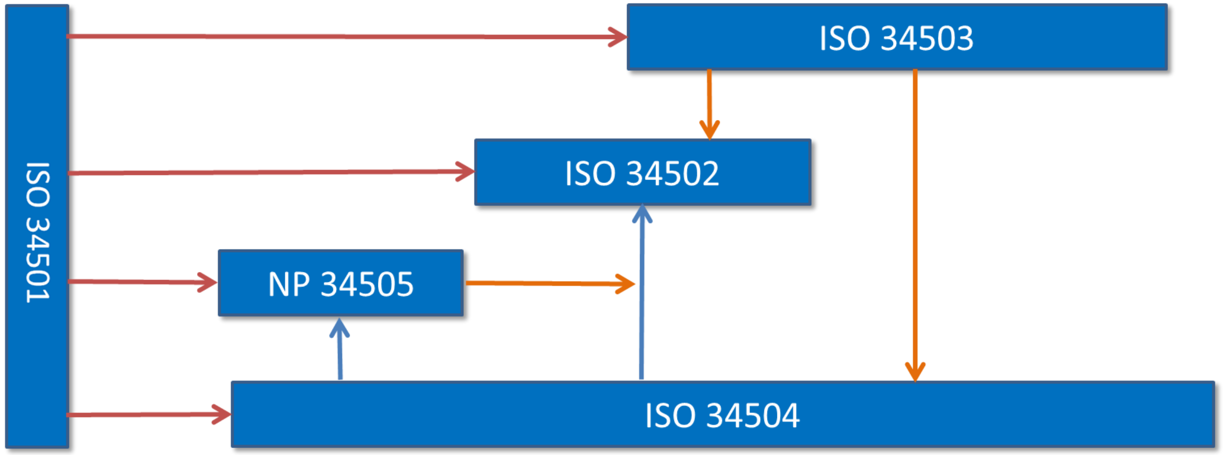


LITERATURE REVIEW

ISO 3450X

- ISO 3450X series provides: terms and definitions of test scenarios, framework for scenario based testing, ODD taxonomy, list of scenarios attributes and categorization, evaluation of test scenarios.

ISO 3450X



Scopes:

ISO 34501: terms and definitions ------> What are the concepts of entity, attribute, scenario, etc.
ISO 34502: methodology for generating scenario ------> How to generate the scenario based on safety consideration.
ISO 34503: ODD description format ------> Which attributes should be addressed in the description of ISO
ISO 34504: categories, attributes and tags for scenario ------> What is the database structure of the scenario.
ISO 34505: scenario quality control & authenticity validation ------> Whether the scenario generated is qualified for testing.

LITERATURE REVIEW

ASAM OpenX

- Provides a portfolio of standards that support scenario based testing via simulation.

OpenX overview

OpenSCENARIO – Dynamic scene description

OpenDRIVE – Static Road Network

OpenCRG – Detailed Road surface

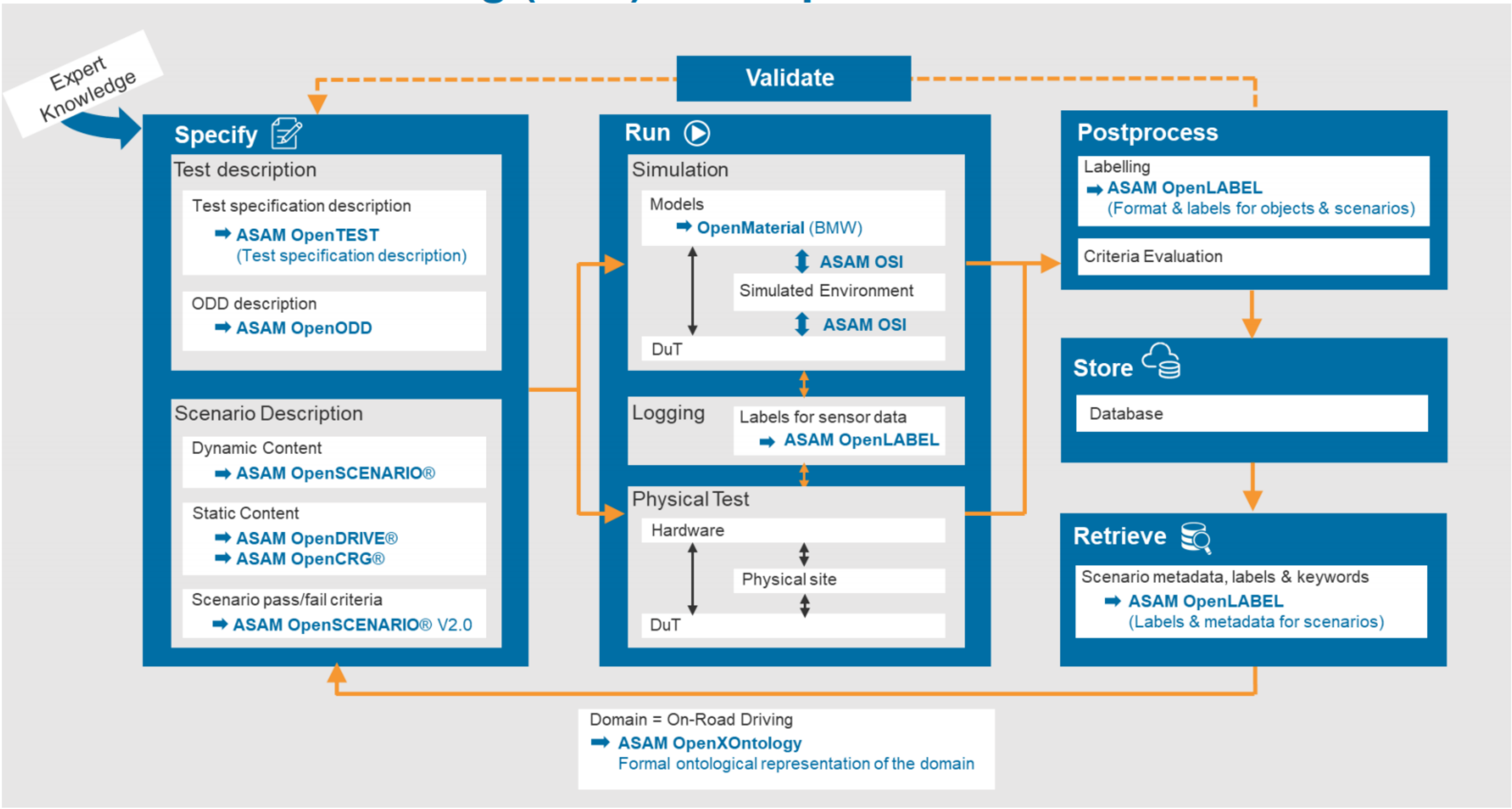
Open Simulation Interface – Interface for environmental perception of AD functions

OpenLABEL – labels and labelling format for obejcts and scenarios

OpenODD – ODD definition format

OpenXOnotology – Extendable domain ontology for on road driving

Scenario-Based Testing (SBT) with OpenX



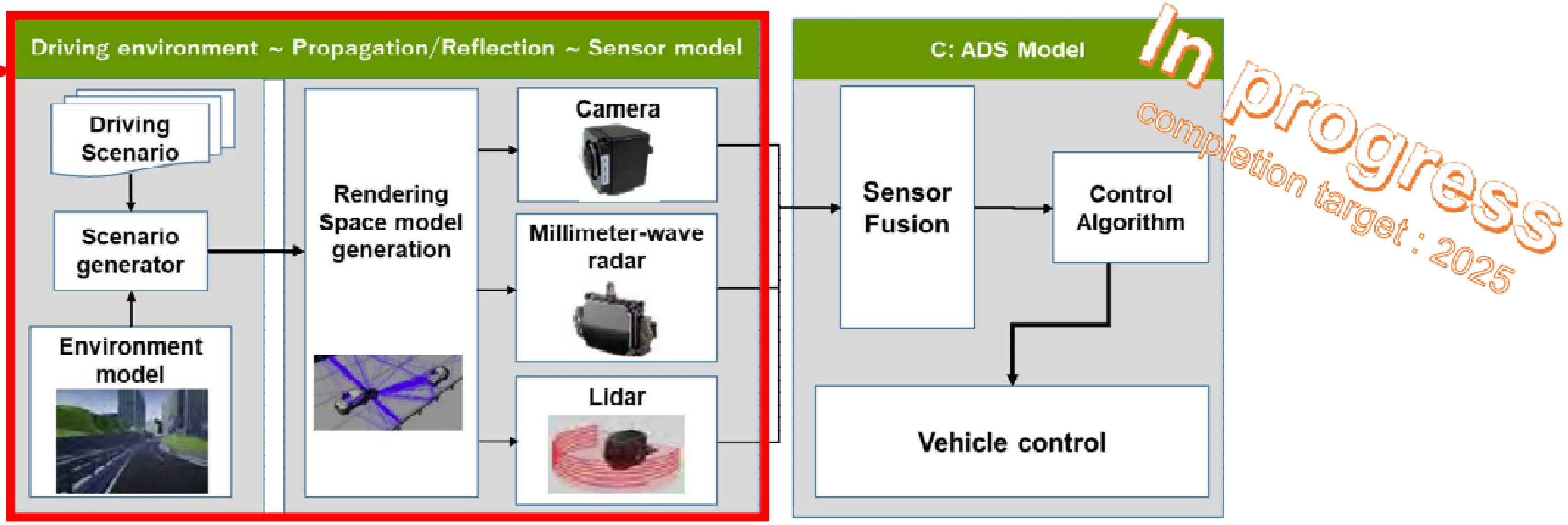
LITERATURE REVIEW

Driving Intelligence Validation Platform (DIVP) – Japan

DIVP

- **Purpose: Highly accurate modeling of environment and sensors <u>related to perception</u>** to enable efficient and comprehensive ADS safety evaluation

Main Target



Environment model		Space model (Signal propagation model)		Sensor model	
3D model	Reflective characteristics	Light source Radio source	Propagation Reflection	Sensor mathematical model	Recognition process

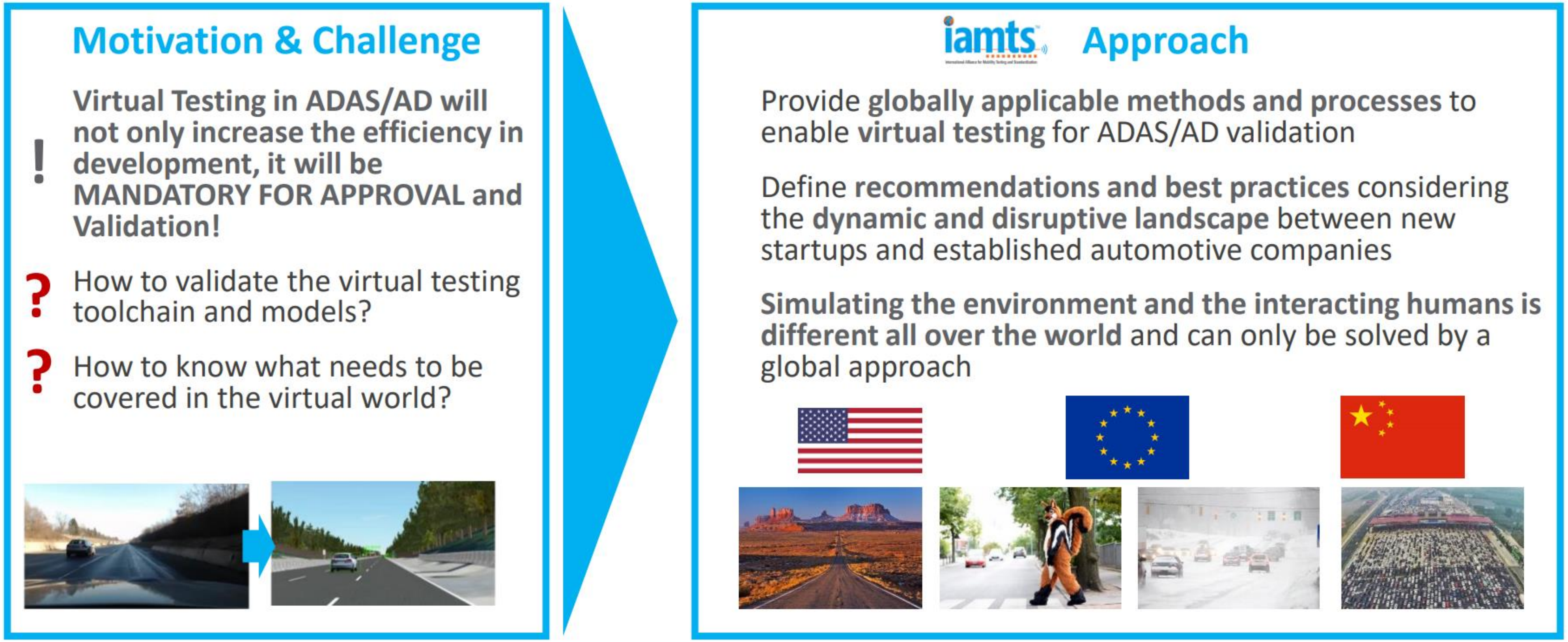
- **Characteristics**
  - **<u>Mathematical modeling of sensor detection principle</u> based on physical phenomena**
  - **<u>Environmental model as sensor input</u> is arranged as Virtual Proving Ground / Computer Graphics**

LITERATURE REVIEW

IAMTS WG 3: Correlation Physical and Virtual Testing

- A general process for step by step correlation is defined.
- A publication will be released with a comprehensive analysis of the correlation methods.
- Physical demonstration will be conducted using concrete examples from UNECE R157 (ALKS).

IAMTS WG3



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LITERATURE REVIEW

NASA's Technical Standard for Models and Simulations (NASA-STD-7009A)

NASA TS

- The standard provides recommendations on data/documentation that should be provided by the simulation provider.

NASA-STD-7009A				
Section	**Description**	**Requirement in this Standard**	**Applicable (Yes or No)**	**If No, Enter Rationale**
4.2.3b	M&S Verification	[M&S 16] Shall document the domain of verification of all models.		
4.2.5a	M&S Validation	[M&S 17] Shall validate all models.		
4.2.5b	M&S Validation	[M&S 18] Shall document the domain of validation of all models.		
4.2.7a	Uncertainty Characterization in M&S Development	[M&S 19] Shall document any processes and rationale for characterizing uncertainty in the referent data.		
4.2.7b	Uncertainty	[M&S 20] Shall explain and document any mechanisms or constructs related to the incorporation		

- The credibility of M&S-based results is not something that can be assessed directly. However, key factors of credibility may be assessed more directly.
- The quality of each factor is scored through a specific assessment. Results are compared to a minimum threshold

Development			Operations			Supporting Evidence	
Data Pedigree	Verification	Validation	Input Pedigree	Uncertainty Characterization	Results Robustness	M&S History	M&S Process/Product Mgt

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LITERATURE REVIEW

NASA's Technical Standard for Models and Simulations (NASA-STD-7009A)

M&S Results Influence					
5: Controlling	(G)	(Y)	(R)	(R)	(R)
4: Significant	(G)	(Y)	(Y)	(R)	(R)
3: Moderate	(G)	(Y)	(Y)	(Y)	(R)
2: Minor	(G)	(G)	(G)	(Y)	(Y)
1: Negligible	(G)	(G)	(G)	(G)	(Y)
	I: Negligible	II: Minor	III: Moderate	IV: Significant	V: Catastrophic
	Decision Consequence				

A 'criticality assessment' is used to determine how rigorously a simulation tool should follow NASA's technical requirements based on: consequences to human safety / mission success, and the degree in which simulated results influence a decision.

- Those simulation that are assessed to fall within the red (R) are clear candidates for fully following this NASA Technical Standard.
- The simulation that are assessed to fall within the yellow (Y) boxes may or may not be candidates for fully following this NASA Technical Standard at the discretion of program/project management in collaboration with the Technical Authority.
- There is not a critical driving force for those falling within the green (G) boxes.

LITERATURE REVIEW

SAFAD

ISO TR 4804 – Safety First for Automated Driving

- Highlights different types of simulation
- Provides a good indication on which simulation types may be useful for all aspects of the HW / SW testing
- Proposes to test the validity of the full system simulation for a subset of corner cases against real-world experience.
- States that the final confidence statement about the automated driving system safety should account for the remaining uncertainty about the validity of the simulation
- It mentions that simulation may be used to estimate the system's behavior after a human takeover

Test Platform and Test Item

Test Item ▶ / ▼ Test Platform	Target SW (Code)	Target HW (ECU)	Vehicle	Driver	Driving Environment
SiL (Simulation in the Closed Loop)	Virtual / Real	Virtual	Virtual	Virtual / None	Virtual
SW Repro (Software Repro-cessing)	Virtual / Real	Virtual	None	None	Virtual
HiL (Hardware in the Closed Loop)	Real	Real	Virtual	Virtual / None	Virtual
HW Repro (Hardware Repro-cessing)	Real	Real	None	None	Virtual
DiL (Driver in the Loop)	Real	Virtual / None	Virtual / None	Real	Virtual / Real
PG (Proving Ground)	Real	Real	Real	Real / Robot	Real
OR (Open Road)	Real	Real	Real	Real	Real

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LITERATURE REVIEW

ISO 26262 Static Analysis

LITERATURE REVIEW

Set Level 4 to 5

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Thank you